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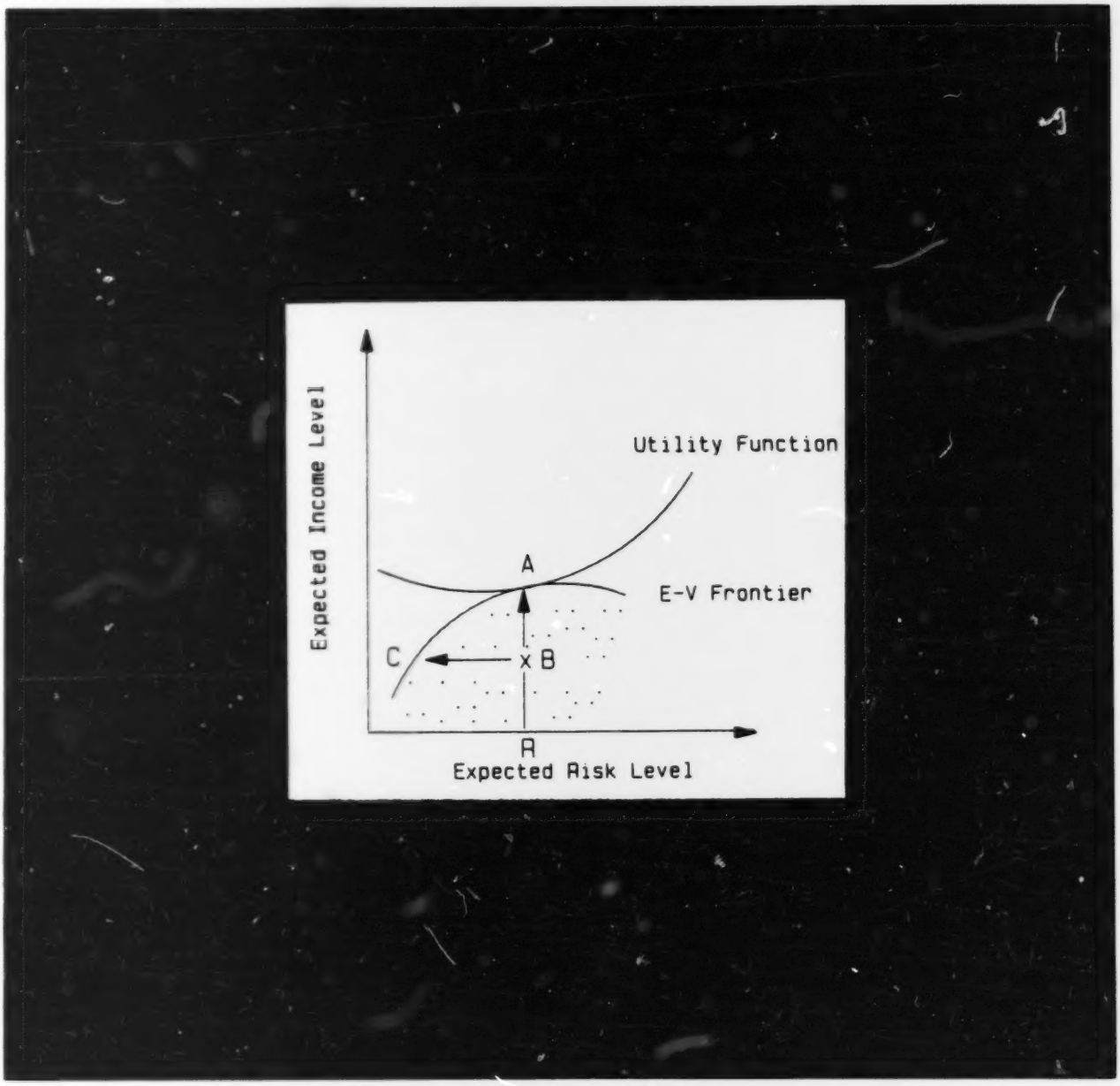
APPLIED RISK ANALYSIS AT THE FARM LEVEL



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ECONOMIC RESEARCH

APPLIED RISK ANALYSIS AT THE FARM LEVEL

by

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INTRODUCTION

The neo-classical economic assumptions that economic activities are carried out in an environment of perfect knowledge have been recognized for quite some time as being unrealistic. Attempts to clarify this assumption have primarily been aimed at including risk in the producer's optimization process of profit maximization. Empirically, this has been done through the use of methods such as linear and quadratic optimization often relating to Expected Income-Variance (E-V) analysis (Turvey and Driver).

At the extension and farm management levels in agriculture, the primary clients are farmers. Farmers and economists are aware that agriculture operates in a risky environment. For the farmer, unlike the economist however, linear programming or quadratic programming approaches to representing risk often have a number of shortcomings. First, the mathematical programming approach requires main frame computers and sophisticated operators to generate solutions. Second, the costs required to generate these solutions for a wide range of agricultural enterprises and a large number of producers are exorbitant. Farmers are therefore left to incorporate risk in their decision making process by subjective analysis. An objective approach to risk analysis at the farm level is therefore required. This approach must, however, be theoretically sound as well as straightforward for it to be utilized by extension and farm management specialists working with farmers.

This paper examines the problem of the theoretical soundness and applicability of applied risk analysis at the farm level. The approach to risk analysis examined is referred to as the "risk rated management strategy" approach which was developed by K.B. Anderson and J.E. Ikerd, Department of Agricultural Economics, Oklahoma State University. Emphasis in this paper will be given to production and market risk.

RISK MANAGEMENT

Risk management is associated with the reality that the production of commodities and the generation of income are not done in an economic environment of perfect knowledge. Specifically, risk management suggests that expected outcomes, whether financial survival, production or prices, have a set of points distributed about them. This distribution is generally represented in agriculture by the normal distribution function. Risk management, therefore, is concerned with the trade-off between expected outcome and expected risk.

Risk is associated with all the activities carried out on the farm. Risk may be classified into three basic groups: financial risk, production risk and market risk.

Financial Risk

Financial risk deals with the probability that a given farm debt to asset structure will facilitate the farm financial survival or bankruptcy. The primary trade-off in this analysis is between percent of owner's equity and probability of bankruptcy. Other factors such as interest rates, of course, play a role in this analysis.

Production Risk

Production risk is concerned with the probability of a farmer attaining a given level of output for specific levels of input. For example, the probability of a farmer in Southern Ontario acquiring a corn yield of 96 bushels per acre is quite high; whereas 150 bushels per acre would be relatively low under normal production practices. Production risk, like financial risk, is influenced by a number of factors. One of the most important factors in production risk is the level of inputs. Increasing the level of inputs and therefore the expected output, causes risk to rise; as a result, production risk is associated with the trade-off between the level of output and risk.

Market Risk

Market risk is concerned with expected prices of commodities and inputs. At the commodity level, grain producers have the alternative of marketing their crop when harvested, or storing it for marketing at a later date. A rational producer who chooses to store grain expects that the difference between the current and the future price will be sufficient to cover storage costs. This expectation is not accompanied by perfect knowledge about the market price, as a result, there is a risk that the actual prices may be higher or lower than were expected. In market risk analysis, the trade-off therefore is between marketing a commodity currently or in the future. This same trade-off can be applied to the purchase of agricultural inputs.

Risk in the cases of finance, production and marketing consistently asserts that trade-offs must be made between expected outcome and the probability of these events. Risk, therefore, prescribes that farmers must have a method of managing risk in a strategic fashion, that is, have a risk management strategy.

Financial, production and market risks facing farmers relate to decisions that are often made in different time frames. Long-term decisions are usually made concerning the financial structure of the farm. As a result, financial risk is often considered to be a long-term factor although short-term activities can change the farmer's equity and cash flow positions. Short-term decisions, on the other hand, are usually made regarding production and marketing - if only because of the seasonality of agriculture. These decisions also can be influenced by long-term and/or medium term decisions, such as the purchase of a new tractor. To a greater extent, however, production and marketing activities are short-term exercises. These exercises usually relate to a one year period. Extension and farm management specialists' major contact with farmers relates to production and market decisions. As a result, the examination of risk in this paper will place emphasis on the management of production risk and market risk.

APPLIED RISK MANAGEMENT STRATEGY

To economists, applied risk management strategy analysis implies a number of things. It may imply E-V, state preference or beta coefficient analysis, but to the farmer all these approaches in their pure form would be alien. Applied risk management strategy at a farm management level requires that farmers be shown how specific farming activities result in the generation of expected income levels with an associated probability or likelihood of outcome.

The theory of risk analysis nonetheless does provide useful considerations on applied risk analysis at the farm level. These considerations can be used as a foundation for examining the theoretical soundness and applicability of a risk rated management strategy approach to risk analysis at the extension and farm management levels.

Of the three theoretical approaches to risk analysis, the E-V frontier approach incorporates many of the principles implicit in the other analyses and is also similar to the risk rated approach. These similarities will become evident in the discussion in this paper.

E-V Frontier Analysis

E-V frontier analysis is based on the premise that risk analysis relates to the trade-off producers make between expected risk, as given by variance, and expected income. The E-V frontier is a locus of the optimal set of points where income is maximum, for a given level of risk and, conversely, where risk is minimum for a given level of income. Graphically, this locus is shown in figure 1.

An optimal mix, A, of expected risk and expected income for a farmer is attained at the point where the utility function is tangent to the E-V curve. The utility function is the locus of optimal points representing how much income or compensation the farmer expects for accepting a given level of expected risk.

The generation of the E-V frontier can be achieved through a number of approaches including parametric linear programming and parametric quadratic programming. A recent approach used in generating the E-V frontier has been to parameterize the Pratt risk aversion coefficient in a quadratic objective function subject to linear constraints (Turvey and Driver, p. 126).

(1) $\max L1 = C'X - (P/2)\, X'QX + W'(B-AX)$

Where C is an nxl vector of expected enterprise returns,

X is an nxl vector of enterprise activity levels,

P is a scalar denoting the Pratt risk aversion coefficient,

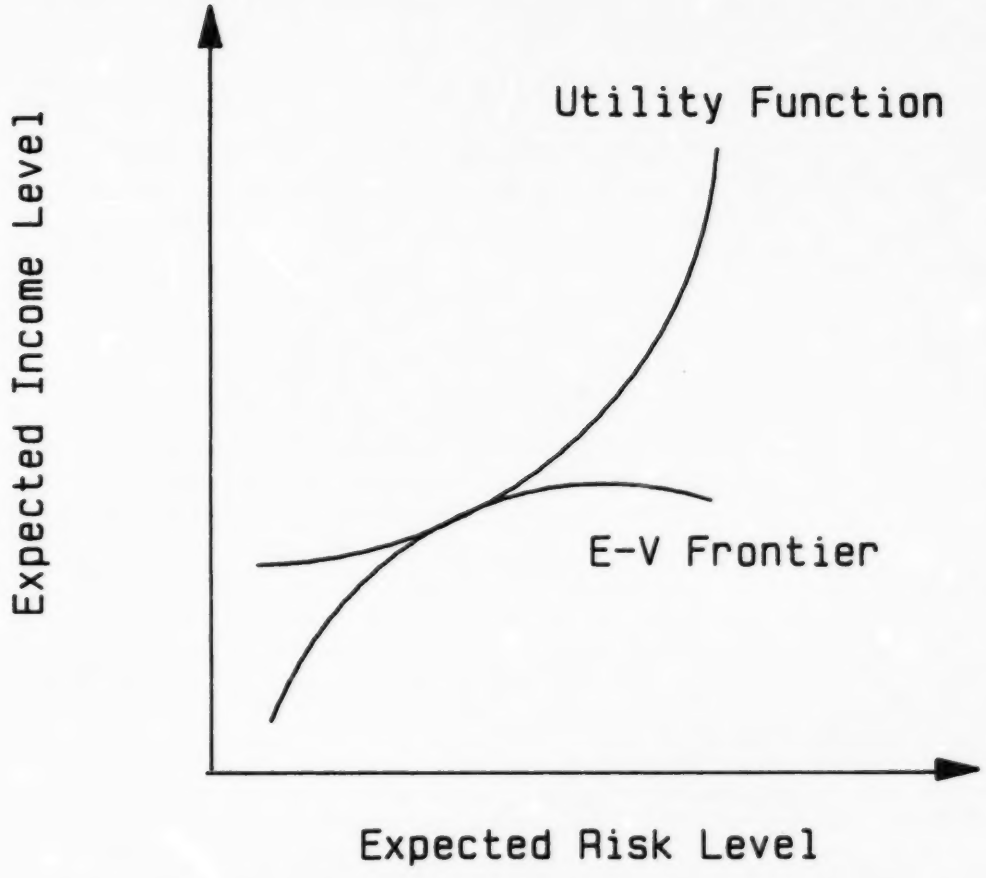
Q is a nxn variance-covariance matrix associated with the returns of the enterprise mix, X,

A is an mxn matrix of technical coefficients,

B is an mxl vector of resource availability, and

W is an mxl vector of shadow values associated with the resource constraints.

Figure 1.—E-V Frontier Analysis



This approach has given results similar to the more traditional approach of minimizing variance subject to linear constraints, while parameterizing the required income level, K (Turvey and Driver, p. 127).

(2) $\min L2 = (1/2)\, X'QX + Y(-B + AX) + Z(K - C'X)$

Where Y is a 1 x m vector

Z is a scalar

Where Y and Z are shadow values on the farm resources and income constraints, respectively.

Theoretically, these approaches to risk analysis are interesting, but are mathematically sophisticated and leave questions unanswered about the farmer's utility function.

To address the issue of farmers' utility functions and the identification of the optimal production set in the E-V domain, it has been suggested that points on the E-V frontier be made available to the farmers for assessment. These points would give the level of expected risk and expected income for different production scenarios. For example, points A and B may have the following income and risk coordinates (Table 1).

Table 1.-- Production Scenario Expected Income Versus Expected Risk

Points	Production Scenario	Expected[a]	
		Income	Risk
		- dollars -	
A	Corn-barley	50,000	20,000
B	All corn	65,000	50,000

[a] Expected income is the mean income and expected risk is the standard deviation about the mean.

Given these two coordinates, the farmer could choose a production scenario, A or B, which best fitted his income expectation and risk preference.

Generating points on the E-V frontier has usually been done through the use of sophisticated mathematical techniques such as those discussed above. This complexity is the primary limitation of applied risk analysis at the farm level. To overcome this limitation, the risk rated management strategy approach seems promising. This approach is a less sophisticated method of generating points representing expected income and expected risk mixes for specific production scenarios.

RISK RATED MANAGEMENT STRATEGIES

Risk rated management strategies have been developed over a number of years by K.B. Anderson and J.E. Ikerd at Oklahoma State University. The fundamental feature of this approach is the use of micro-computer spreadsheet programs to allow the farmer to enter production data (quantities and prices) into a budget generator.

The spreadsheet is formatted similar to budgets already produced by many extension and farm management specialists. In the case of Ontario, the spreadsheet budgets have been formatted to match those traditionally produced by the Ministry of Agriculture and Food. The overall calculations of the budgets generate expected net farm income for an enterprise or the whole farm.

Risk is incorporated into the budget by allowing the farmer to input high (optimistic) and low (pessimistic) coefficient values into the budget. These values are entered in addition to the expected values which are usually found in extension and farm management budgets. To represent production risk, optimistic and pessimistic values are inputted for items such as yield for crops and average daily gain for livestock. For market risk, these extreme values are inputted for output prices and input prices. Extreme values around input prices are of particular importance for livestock enterprises where animals may be purchased for finishing.

In the example, the expected yield is 120 bushels per acre with a possible low or pessimistic level of 95 bushels per acre and an optimistic level of 150 bushels per acre (Table 2). The expected price per bushel is $2.40 and the extreme values are $2.80 and $2.10 on the high and low side, respectively. The optimistic level is attained by asking the farmer for the best case expected in six years, while the pessimistic level is acquired by asking the farmer for the worst case expected for the same time period.

The risk rated budget, therefore, allows the farmer to input expected values and extreme values for a given production scenario. These values are then used to calculate expected net returns and expected risk, as measured by the variance. Additionally, the probability of the farmer breaking even or attaining a required level of income is also calculated.

Table 2.—Grain Corn Enterprise Budget[a]

Items	Optimistic	Expected	Pessimistic
Yield bu./ac.	150	120	95
Price, $/bu.	2.80	2.40	2.10

[a] The numbers in all the tables of this report are only for illustrative purposes and do not necessarily represent an actual situation.

Table 3.—Grain Corn Enterprise Budget, Variable Costs

Expense	Unit/ Acre	Amount Used	Cost/ Unit	Cost/ Acre
				- dollars -
Variable Costs:				
Seed	M-kernel	26	0.96	25
Seed Treatment				1
Fertilizer				
#1 8-32-16	kg	70	0.26	18
#2 82% N	kg	55	0.34	19
Herbicide				
Annual Grasses	kg or L	1	13	13
Broadleaf Herbicides	kg or L	1	4	4
Other Herbicides	kg or L	0	0	0
Insecticides	kg or L	3.2	3.5	11
Fungicides	kg or L	0	0	0
Crop Insurance	$	1	7	7
Custom Charges	$	0	0	0
Drying 8 Points	tonnes	3.35	15.5	52
Storage	tonnes	0	0	0
Trucking	tonnes	3.05	6.5	20
Marketing Fees	acre	0	0	0
Other	acre	0	0	0
Fuel				15
Machine Rep. & Maint.				21
Short-term Commitments				15
General Variable Costs				10
Interest on Op. Capital (12% for 6 months)				13
Total Variable Costs				243

Table 4.—Grain Corn Enterprise Budget, Fixed Costs

Fixed Costs	Default[a]	Enterprise Allocated	Total
		- $/acre -	
Depreciation	16.5	0	17
Interest on Loans	41	0	41
Long-term Commitments	20	0	20
General Fixed Cost	25	0	25
Total Fixed Costs			103

[a] Default data represents data which could be county averages on specific cost items. A specific farmer could change these numbers to have it more representative to his/her particular operation.

Table 5.—Grain Corn Enterprise Budget, Expected Net Revenue and Breakeven Price

Items	Area
	$/acre
Total Costs	345
Total Expected Revenue	288
Expected Net Revenue	- 57
Breakeven Price (120 bu./ac.)	$/bu.
Variable Costs	2.02
Fixed Costs	0.85
Total Costs	2.88

These calculations are carried out through the following steps:

1. Expected net returns:

$$NR = PY - Px\ X$$

where
- NR - Net returns
- P - Output price(s)
- Y - Output(s)
- Px - Input price(s)
- X - Input(s)

2. Variance on returns[1]:

$$V_y^2 = (Y_{op} - Y_{pes})^2/2$$

$$V_{p_2}^2 = (Pop - P_{pes})^2/2$$

$$VT_{nr} = V_y^2 + V_p^2 + 2\ rVyVp$$

where
- op - Optimistic
- pes - Pessimistic
- V_y - Standard deviation of output
- V_p - Standard deviation of output price
- VT_{nr} - Total standard deviation
- r - rho, correlation coefficient

3. Probability of a given level of required income (RI) per unit (e.g. acre, head, cwt.):

$$Z = \frac{NR - RI}{VT_{nr}}$$

where
- Z - Z statistic
- RI - Required Income

---

[1] Only variances for output and output prices are shown here, however, variances could also be calculated for factors using the same method.

For step 3, one could use a Z statistic table to determine the probability of the farmer attaining a required income. Since the budgets can be used to calculate net returns, a required income of zero by implication is the breakeven point. Additionally, rates of return on land and other items can be excluded from the budget but included in the required income such that the results of the budgets provide a farmer with the probability of at least attaining a given return on land or any other factor of production.

The three steps outlined in generating risk rated budgets are operational and do work. However, the process of examining Z statistic tables in step 3 would likely be unclear to the farmer. As a result, the normal distribution function was incorporated in the spreadsheet budgets using an equation that estimates the density of the normal distribution function given a Z statistic (Appendix, p. 13). Using the variance and Z value, a breakeven analysis with the chance of success is produced (Table 6).

Table 6.—Returns Analysis and Chances of Success

Level of Return	Chance
$/acre	%
60	7
21	16
0 [a]	23
- 18	31
- 57	50
- 97	31
- 136	16
- 175	7

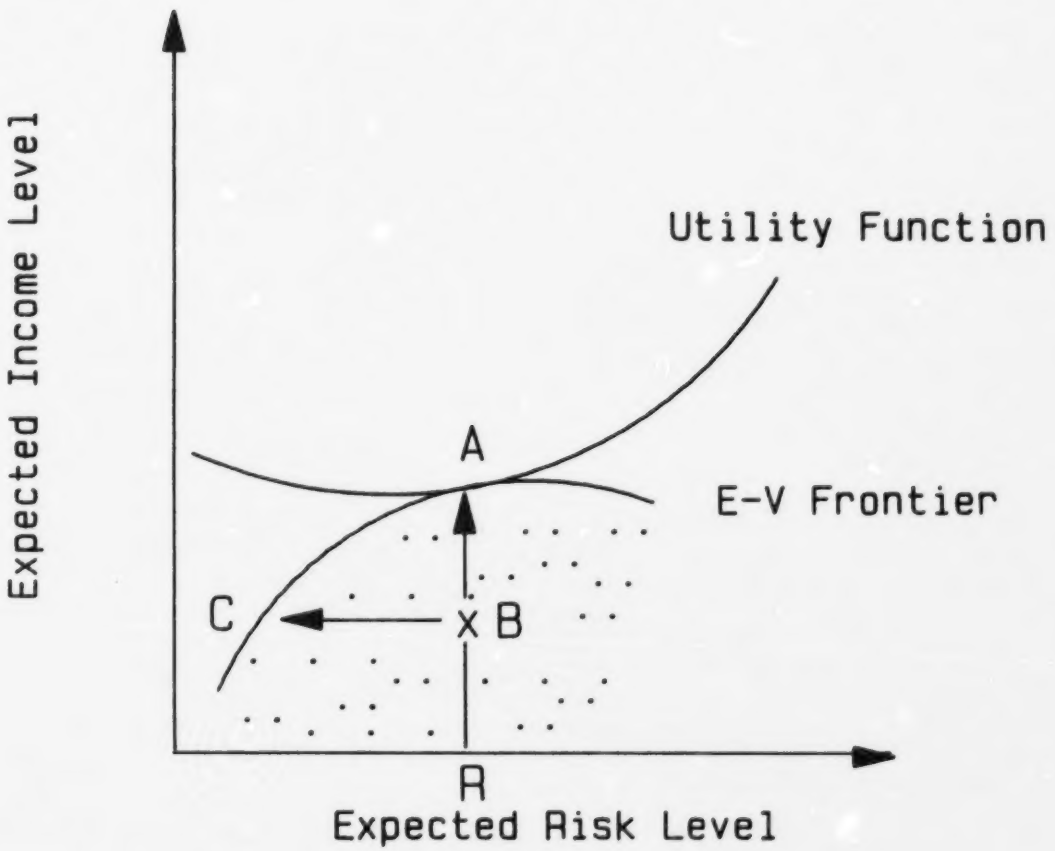
[a] This is the breakeven point with a probability of 23 percent.

The information generated by the risk rated budget is summarized in Tables 5 and 6. Table 5 shows expected net returns and breakeven prices, while Table 6 gives the probability of at least attaining these levels. The information in Table 6 can be interpreted, for example, as suggesting a farmer may have a 7 percent chance of at least earning $60 per acre while also having a 50 percent chance of losing $57 per acre given the current production scenario.

The farmer, after examining the risk rated budget information, may attempt to examine alternative production plans. Each of these plans in turn generates a point corresponding to a given level of expected income and expected risk as was shown in the example (Table 1). Plotting a number of these points would produce a scatter diagram relating expected risk to expected income. The dots in Figure 2 represent this scatter diagram.

Joining the points on the scatter diagram where expected income is maximum for given levels of risk, forms a curve. This curve satisfies the same conditions as

Figure 2.—E-V Frontier and Scatter Diagram



the E-V frontier in E-V analysis and, in actual fact, is the E-V frontier. The intent of having the farmer generate repeated solutions is to expose him to those production scenarios which are likely to be on the E-V frontier as opposed to those inside it. Points inside the E-V frontier are sub-optimal since for a given level of risk, R, choosing a point inside the E-V frontier, B, will yield less expected income than a point on the curve, A, for the same risk. As well, point B will yield the same income but at more risk than point C (Figure 2).

The risk rated management strategy approach, therefore, can generate the E-V frontier in a similar manner to the mathematical programming approach but in a less mathematically sophisticated way than those outlined by Turvey and Driver and other academics. A limitation of the risk rated approach, however, is that there is no guarantee that the farmer's production scenarios are feasible on his farm. As a result, the farmer may identify a production scenario which will give him his desired mix of expected income to expected risk, but which is also infeasible on his farm. Additionally, the choice a farmer makes is dependent on his perception of how well the risk rated budget approach has related actual production and marketing risk to him. These two limitations, however, do not eliminate the value provided by risk rated budgets in providing an empirical representation of risk to farmers. As a result, the risk rated budgets can augment producers' subjective evaluation of risk with empirical results.

CONCLUSIONS

The risk rated budget approach has been shown to be consistent with the economic theory of risk, particularly, the E-V approach. The risk rated budget approach therefore provides producers and agricultural researchers with a simple method of applying risk analysis. The benefit of this method is that producers' subjective evaluation of risk can be augmented with empirical results which relate expected income and expected risk to specific production activities. However, the usefulness of this information to farmers in Ontario, is of course, a matter of faith until the approach has been fully tested. Nonetheless, the risk rated management strategy approach is a practical and likely effective representation of risk at the farm level.

An inference for further studies emanating from this paper relates to the generation of E-V frontiers by farmers themselves as opposed to researchers. Farmers could use the risk rated budget approach to generating the E-V frontier, while researchers could use the contemporary optimization approaches. The two E-V frontiers developed by these two approaches may be found to be significantly different from each other. These differences may suggest that the way in which farmers and researchers allocate resources, trade off income to risk, and optimize objective functions may differ. Differences in E-V frontiers might also be linked to how researchers handled management in their model. Finally, it is also possible that the risk rated budget approach and contemporary optimization approaches are sufficiently similar that the E-V frontiers generated are basically identical.

APPENDIX

NORMAL DISTRIBUTION - DENSITY FUNCTION ESTIMATION

$$f(X) = \frac{1}{V\,2TT} \exp\left[-\frac{1}{2}\left(\frac{X-\bar{X}}{V}\right)^2\right]$$

Where:

$\bar{X}$	is The mean
V	is The standard deviation (VTnr)
X	is specific observation
TT	is pi (3.14159..)

Known:

$$Z = \frac{X - \bar{X}}{V}$$

Standard Normal Distribution:

$$\bar{X} = 0 \text{ and } V = 1$$

$$Z = \frac{X - 0}{1}$$

$$Z = X$$

Hence:

$$f(X) = \frac{1}{2TT} \exp -(X^2/2)$$

Total Area Under the Density Function:

$$\int_a^b \frac{1}{2TT} \exp -(X^2/2)\, dX = 1$$

$$P(a \quad X \quad b) = \int_a^b \frac{1}{2TT} \exp -(X^2/2)\, dX$$

ESTIMATE OF NORMAL DISTRIBUTION DENSITY FUNCTION

$$P(VX) = C_1 * (a_1 C_2 + a_2 C_2 + a_3 C_2 + a_4 C_2 + a_5 C_2)$$

$$P(VX_2) = 1 - P(VX)$$

$$C_1 = \frac{1}{2\pi} \exp(-Z^2/2)$$

$$C_2 = \frac{1}{1 + C_3 Z}$$

The equation P(VX) estimates half of the integral of the normal distribution density function. Since the function is symmetrical, only half is needed.

Note: C_3, a_1 ... a_5 are constants.

RESULTS OF THE RISK RATED BUDGETS

Chance of Breaking Even $P(VX)$
Change of RI $/Unit profit $P(VX_2)$

Return $/Unit			Chance
X_1	=	$X + Z_1V$	7%
X_2	=	$X + Z_2V$	16%
X_3	=	$X + Z_3V$	31%
X_4	=	$X + Z_4V$	50%
X_5	=	$X - Z_3V$	31%
X_6	=	$X - Z_2V$	16%
X_7	=	$X - Z_1V$	7%

Z Value taken from Z Statistics Table:

Probability Levels P (X)	Z Values
7%	1.5 = Z_1
16%	1.0 = Z_2
31%	.5 = Z_3
50%	0 = Z_4

Known $Z = \frac{X - \bar{X}}{V}$

$\bar{X} + ZV = X$

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